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PRODUCTION OF HOPS

U.S. DEPARTMENT OF AGRICULTURE

HOPS were at one time grown in many of the States, but they have never been an important crop except in New York and the Pacific Coast States. After the advent of prohibition, the crop was practically abandoned in New York but has been revived there in recent years. On the Pacific coast, hop growing has for many years been an important industry.

The harvested hop acreage in the United States declined from more than 40,000 to less than 20,000 acres during the period of national prohibition. With the legalization of beer in 1933, there has been a general increase in acreage. However, higher production costs, losses from diseases and insect pests, and uncertainties of the market have been consistent factors in preventing undue expansion of the acreage.

This bulletin tells where hops are grown commercially in the United States. The equipment and methods used in producing the crop and preparing it for market are described, and the control of insect pests and diseases to which hops are subject is discussed.

This publication is a revision of and supersedes Farmers' Bulletin 304, Growing and Curing Hops.

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PRODUCTION OF HOPS[1]

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INTRODUCTION

HOPS CAN BE GROWN throughout the United States, but at present extensive commercial production of the crop is restricted to sections in the States of California, Oregon, and Washington. In years past, the crop was grown largely in New York, and to a smaller extent in Wisconsin. Also, small quantities were formerly produced in several other North Central and Eastern States. Early in the present century, the industry began to decline in New York, with a gradual shifting to the Pacific Coast States, where it is now centered. In recent years, however, interest in hop growing has been revived in New York, and increasing quantities are again being produced.

Figure 1 indicates the distribution of the hop-growing sections in the United States and shows how the industry has become sharply localized in certain districts where the most favorable conditions apparently prevail.

It is impracticable to describe in detail all the conditions essential to profitable hop production or all the methods of hop growing that could be applied with equal success in all parts of the United States. The conditions of soil and climate and the varieties grown determine

[1] This bulletin is based on cooperative investigations by the Division of Drug and Related Plants, Bureau of Plant Industry, and the Oregon Agricultural Experiment Station.

[2] Acknowledgment is made to specialists of the Oregon State College for furnishing some of the information for this bulletin and for reviewing the manuscript, especially in connection with the preparation of the section on Insect Pests and Their Control.

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largely the methods of culture followed in any one locality. The practical grower should adopt those methods that, according to local practice and his own experience, are best suited to his conditions.

CLIMATE

Hops are grown commercially under a wide range of climatic conditions. Long and severe winters, however, frequently kill out many of the plants, particularly in newly planted yards. They are produced most successfully in the milder regions where abundant early rainfall is followed by warm dry weather as the crop approaches maturity. Continued cold, damp, or foggy weather in the spring may unduly delay normal field operations and result in retarded and weakened growth of vines. These conditions also favor the development and spread of downy mildew—the most serious

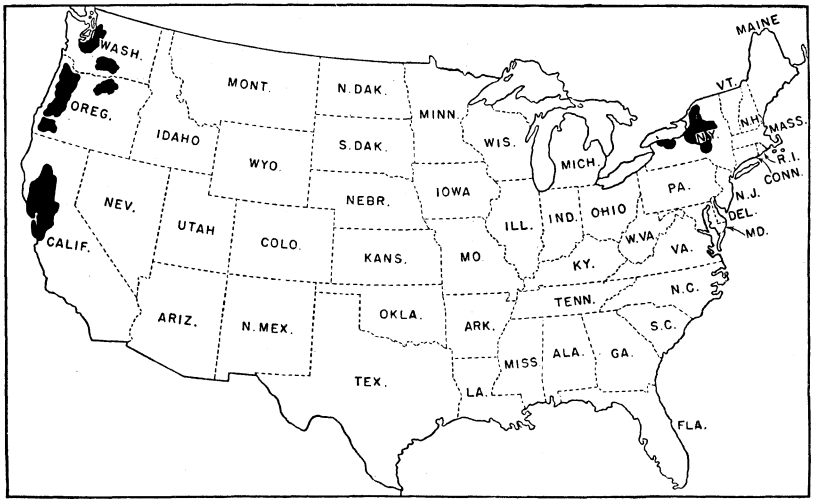

FIGURE 1.—Map showing the hop-producing districts of the United States.

disease to which the plant is subject. Extremely dry seasons or hot dry winds of long duration have an unfavorable effect on the normal development of the vines. The response of the hop plant to ample and timely irrigation is marked. The method and extent of irrigating differ with the soil, the season, and with the practices common to the sections in which the hops are grown. In some sections proper drainage should be given careful consideration. Excessive rainfall in the harvest months—August and September—frequently results in heavy damage from lice, molds, and downy mildew.

SOILS AND FERTILIZERS

The selection of the best soil in which to grow the hop plant involves the consideration of several factors. In general, rich alluvial lands or deep sandy or gravelly loams are preferred. Soils with a high percentage of sand are readily tillable, whereas the cultivation of stiff soils is difficult and expensive. Owing to differences in the

amount of rainfall and sunshine, and in the force of the prevailing winds, lands suitable for hop culture in one region may be entirely unsuitable in another. Because the roots of the hop plant penetrate many feet, a well-drained subsoil is essential. Special attention must be given to the depth, fertility, drainage, and fineness of the soil. Heavy wet soils should be avoided, and stiff clayey soils are in general disfavor. Soil maps are available for most of the California and for all of the Oregon hop-growing districts, and growers should consult them to determine the suitability of any particular locality.

Careful consideration of the soil types on which the hops are planted, together with previous cropping history, will serve as a sound basis for the development of a fertilizer program. Hops require nitrogen, phosphorus, and potash for their full development and deplete the soil of these elements. It is necessary, therefore, to return these to the soil in the form of fertilizers, if both yield and quality are to be maintained. Many river-bottom soils on which hops are grown contain the necessary plant nutrients; hence, except for maintaining the content of organic matter, little, if any, fertilizer is necessary. Such soils show no marked results from adding fertilizing materials. The old vines from which the hops have been picked, if not too badly diseased or too heavily infested with insect pests, may be used to advantage in increasing the organic matter in the soil, or they may be burned and thus add appreciable amounts of fertilizing elements.

A deficient vine and leaf growth and light-green or yellow foliage usually indicate a lack of nitrogen. A decrease in the yield of cones or seed and a delay in ripening are usually due to a lack of phosphorus. This element also stimulates root development in young plants. Sandy soils often lack potash. Where there is a limited amount of organic matter in the heavier soils, there may be a deficiency in readily available potash, even though there is an abundant total supply. Some poorly drained soils, although often well supplied with organic matter, respond favorably to potash applications. Stable manure at the rate of 10 to 20 tons per acre will usually supply sufficient nitrogen and potash, but it is deficient in phosphorus. To supply this lack, 40 pounds of 18-percent superphosphate should be added to each ton of manure. The fertilizing value of other organic materials, such as waste legume hay or grain straws, which are sometimes more readily available and often cheaper, should not be overlooked.

A common practice on the Pacific coast is to apply inorganic fertilizers in the spring at hoeing time. The materials are usually placed in a circle 6 to 10 inches from the crowns of the plants (fig. 2), care being taken to prevent their coming into too close contact with the roots, particularly of young plants. New plantings and "resets" should usually receive smaller applications than well-established plants. Applications range from one-fourth to as much as 1 pound or more per hill. Usually smaller amounts are used when hill applications are made than when broadcasting is practiced.

From 150 to 400 pounds of 20-percent nitrogen is recommended, half of which should be in quickly available form. An application of a readily available form of phosphate such as superphosphate at

the rate of 300 to 500 pounds per acre is advisable. Muriate of potash at the rate of from 100 to 200 pounds per acre is suggested for supplying potash.

All fertilizing materials should be thoroughly incorporated in the soil as soon after being applied as possible.

The use of cover or green-manure crops as fertilizers is a highly desirable practice that merits more general use. Cover crops prevent washing or erosion of the soil and leaching of soluble plant foods during winter months, and also increase the water-holding capacity of the soil. They not only add organic matter, which, when properly decayed, increases fertility, but also tend to make inorganic chemical nutrients in the soil more readily available and improve the general tilth of the soil by increasing aeration. To a slight degree, they probably increase soil temperatures.

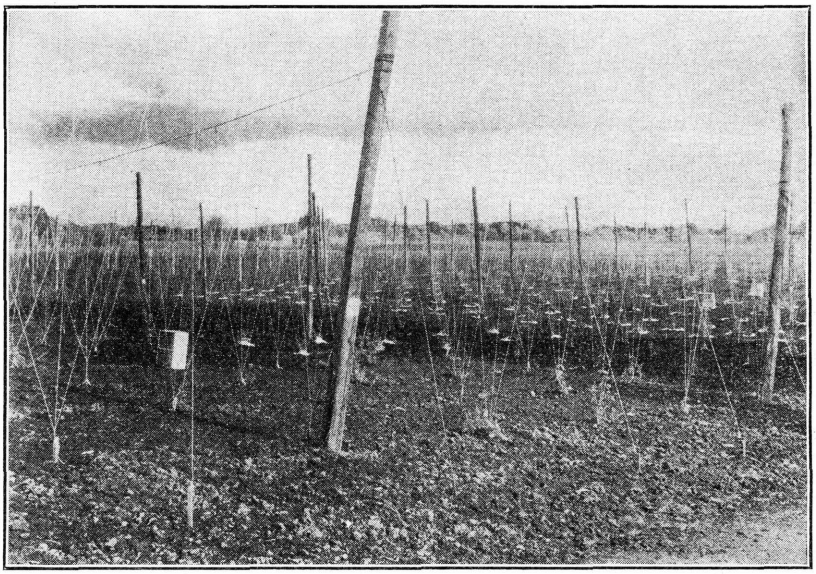

FIGURE 2.—Commercial fertilizer applied to individual hills.

In general, leguminous crops are to be preferred because of better growth, larger root systems, nitrogen-gathering ability, and rapid decay. These crops are usually seeded in the fall immediately before harvest and turned under early the following spring (fig. 3). The hop growers should choose those that do best under local conditions and of which seed is cheapest and most readily available. Some growers use a mixture of legumes and winter grains or depend entirely on winter grains for a cover crop. The customary heavy growth of the grains is not so desirable unless it is turned under very early in the spring. Occasionally, cultivated turnips and "wild mustard" are used. During some seasons, in certain of the Pacific coast hop-growing sections, natural wild growth of weeds is sufficiently abundant to be of some value for green manure but in general should not be depended on to provide large supplies of organic matter, especially on the more sandy soils.

PROPAGATION

Hops are commonly propagated from "root" cuttings and not from seeds, because seedlings show little uniformity in the variety of hops produced and tend to vary greatly in the time of ripening. Also, seedlings require more than one season to produce satisfactory yields.

USE OF CUTTINGS

Vigorous plants are most easily and quickly secured by the use of cuttings. This procedure constitutes the simplest and most practical commercial method of growing hop vines. The cuttings are actually sections of underground stems, but are commonly referred to as "root cuttings" or "roots." In some localities rooted cuttings that have

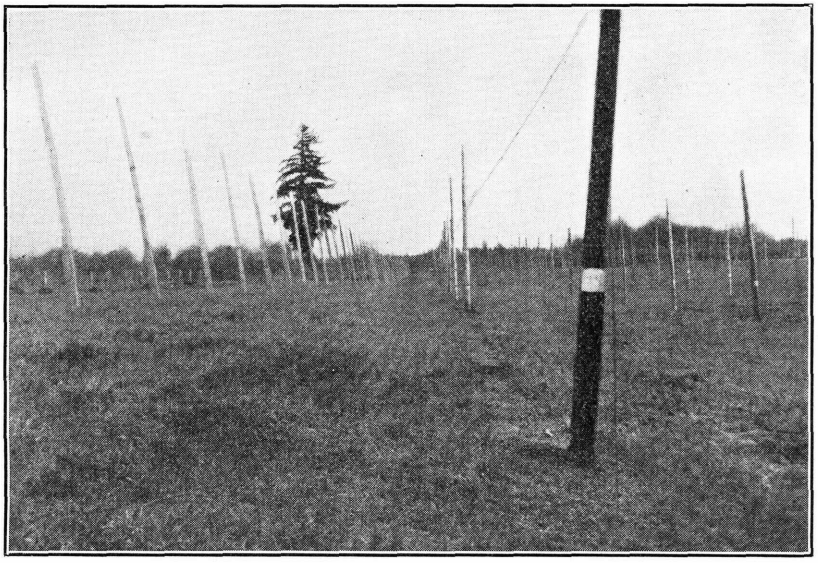

FIGURE 3.—Cover crop of winter barley and vetch, early in the spring.

been in the nursery for 1 year are called sets. The numerous runners sent out by the hop plant just below the surface of the ground are usually removed when the plants are pruned in the spring, and these, preferably one-half inch in diameter, are cut into pieces approximately 6 to 8 inches long, each piece bearing at least two pairs of buds or "eyes." These are used to produce new plants. In some sections of the Pacific coast a crop may be obtained from cuttings planted in the spring, but generally a full crop is not harvested until the second or third year. All cuttings should be carefully inspected before planting and those that are poorly developed, misshapen, damaged, or diseased should be rejected (fig. 4). If the cuttings are not planted immediately, they should be stored in a cool, moist, well-ventilated place to prevent drying out. Care should be taken, however, to prevent the development of molds or rots, premature sprouting, or freezing.

VARIETIES

The four principal varieties of hops in the United States are Late Clusters, Early Clusters, Fuggles, and Red Vine. The first and most important is thought to have been introduced from Europe, but its exact origin is unknown. It was brought to the Pacific coast from the Eastern States. Early Clusters is presumed to have originated in Oregon as a chance selection from Late Clusters. Fuggles was doubtless imported from England. Red Vine, which is said to have come from Canada, is not usually grown in unmixed plantings. In Oregon, Late Clusters comprises about 70 percent, Early Clusters 15 to 20 percent, and Fuggles 10 to 15 percent of the commercial crop. Fuggles is first to mature, followed by Early Clusters and Late Clusters. The last-named variety produces the highest average yields, and Fuggles the lowest. In some seasons higher commercial yields

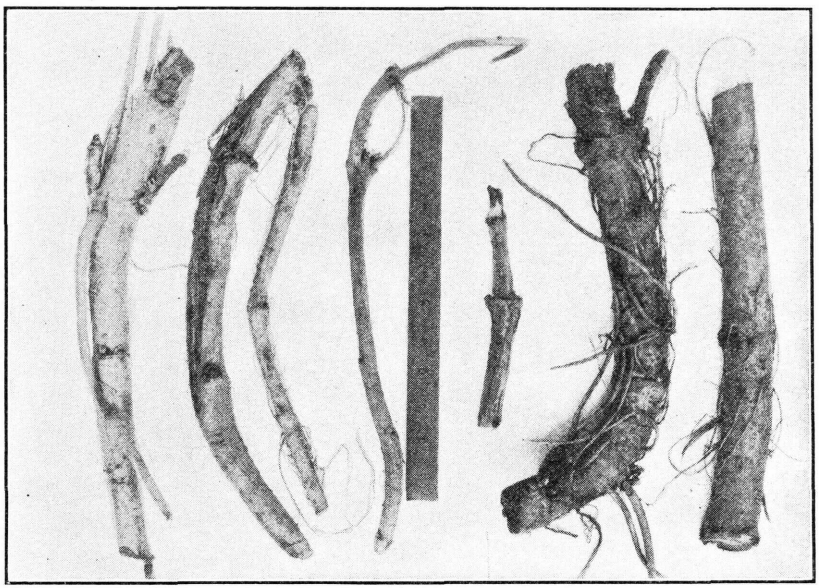

FIGURE 4.—Undesirable types of cuttings.

are reported for Fuggles than for either of the Clusters varieties because it is more resistant to downy mildew. As Early Clusters is highly susceptible to this disease, practically the entire acreage in western Washington is devoted to the production of Fuggles, and most of the yards in the eastern part of that State are planted to Late Clusters. Although not unmixed, all California hops are similar to, if not identical with, Late Clusters.

ORIGINATING NEW VARIETIES BY SELECTION AND HYBRIDIZATION

The opportunity for improving existing varieties or for producing improved sorts by selection of the stocks from which cuttings are taken offers a promising field for the progressive hop grower. In almost every field, mixed varieties and light and heavy producers occur indiscriminately. Where the number of low-yielding hills is

large, the total yield will be correspondingly reduced. Such hills should be removed and replaced by cuttings taken from plants giving high yields. Male plants grown intentionally for seed production are seldom planted systematically, and many yards contain more males than are needed for pollination. If every tenth plant in every tenth row is a male, the desired result is obtained. Many yards also have male plants that shed their pollen either too early or too late to be functional in pollinating the female flowers when they are normally in a receptive condition. In many instances, too, the male plants are hermaphrodites, i. e., they bear both male flowers and cones and are undesirable for either purpose. Sexless, sterile plants, commonly called "bastards," are all too common. Their presence is due to the unusual vegetative vigor of their underground stems, which encourages growers to use them in resetting missing hills. Dormant hills or "sleepers" occur in appreciable percentage in many yards. Shoots from such hills are late in developing in the spring and often produce belated and irregular stands of vines. All of the above-mentioned abnormal types should be discarded or marked for discarding during the growing season as soon as the abnormalities become evident, as it is impossible to identify some of them after the vines are cut. It is a good practice to avoid the use of cuttings from any vegetatively weak, off-type, abnormal, diseased, or unhealthy plants.

A decided improvement in quality should follow the careful selection of cuttings with reference to productiveness, uniformity, disease resistance, and general adaptability to the cultural conditions in the region where they are to be grown. The selection should be made just before harvest, when the hills containing plants of superior quality and productiveness can be staked so that cuttings may be secured from them the next season. The practice of establishing a nursery plot in which cuttings from particularly desirable plants are grown for the purpose of developing a source of improved planting stock is worthy of more general use.

The originating of new varieties and the improving of existing varieties by selection merit the attention of every hop grower. However, such work is best undertaken by the plant breeder. Plant selection consists in taking cuttings from a plant of exceptional quality and thus increasing the planting stock for developing an improved variety. Growers can employ this method, as was done when the Early Clusters variety was developed, but it usually requires more time, care, and patience than they can or will devote to it. Hybridization or crossing requires the use of plants raised from seed, and, being a procedure too complicated for most growers to undertake, it is seldom employed commercially.

FOREIGN INTRODUCTIONS

Early Clusters, Fuggles, and Late Clusters have become acclimated to the hop-growing sections of the Pacific coast. Growers are familiar with their cultural characteristics and requirements, the physical and chemical qualities of the crops they produce, and the pests and diseases to which they are subject.

Many hop growers are inclined to neglect the possibility of improving the planting stock at hand in their attempts to introduce other

foreign varieties, the comparative values of which have not been determined. The commercial results secured from such efforts are often disappointing. In any event, foreign introductions by growers are not advisable unless planting stock is cleared through official channels where rigid inspection of such stock is made to detect the possible presence of insect pests and diseases that might be overlooked by the grower. Despite established quarantine restrictions, present procedure cannot be expected to detect such important maladies as the various virus diseases to which hops are subject. If some of these diseases became established in commercial hop-producing sections, disastrous results to the industry might follow.

The introduction, testing, and eventual distribution of the more promising foreign varieties are best undertaken by experiment stations qualified to conduct such an important, complicated, and time-consuming program.

SEEDED AND SEEDLESS HOPS

Hops may be produced either with or without seeds. Domestic hops usually contain seeds in varying quantities, whereas most imported hops are seedless. However, in recent years domestic seedless hops have made their appearance in increasing quantities in the market.

Hops are dioecious or unisexual, that is, the male and female flowers are borne on separate plants. The seed content is determined by the variety of the hops and the extent to which the female inflorescences are fertilized by the pollen from the male plants. In this country it is a common practice to allow one male plant in the fields to about every hundred female plants. The greater the number of male plants in the field, the more female flowers are fertilized and the higher the percentage of seeds formed. Seeded hops have been observed to contain from as little as 4 percent to as much as 30 percent of mature seeds. Such hops are heavier because, in addition to the weight of the seed, on the average, the cones are considerably larger than seedless cones and therefore the yield is correspondingly greater. However, the effect of seeds on the quality of hops is an important consideration. It is generally conceded that seeds in hops are extraneous and undesirable and play no favorable role in brewing. This fact may be, at least in part, the reason the brewing trade considers seeded hops inferior in quality to the seedless type. In lupulin content hops of the seedless type do not differ materially from seeded hops.

Seedless hops may be produced by the elimination of male plants from the hop fields, thus preventing pollination and subsequent seed formation. However, only the complete exclusion of male plants from a field and the absence of male plants in adjoining fields will produce hops that are entirely seedless. The chance of a female flower receiving pollen depends largely on its proximity to the male plant, direction of the wind, and condition of the weather. Because seedless hops are more compact and the cones are smaller in size, their yield is estimated to be approximately 30 percent lower. Moreover, because of their small size the cost of picking is correspondingly higher; also, they contain a higher percentage of moisture and hence lose more weight in drying than do normal seeded hops. For these reasons

growers may be somewhat reluctant to produce seedless hops unless the decreased yield and increased cost of production is more than offset by a corresponding increase in price. Inasmuch as complete elimination of pollen cannot be expected in districts where there are many yards in close proximity to one another, growers in such districts will doubtless continue to produce seeded hops. Nevertheless, since brewers in recent years are inclined to favor seedless hops because of their superior brewing qualities, growers should give careful thought and consideration to the feasibility of producing such hops in order to satisfy in a greater measure the exacting demands of the trade.

TIME TO PLANT

The time at which planting is done depends very largely on the local conditions where the crop is grown. In general, the best results are obtained by planting in the spring as soon as the soil can be worked into a fine mellow condition. Occasionally, when plowing is delayed by heavy rains or floods, the pruning and resetting of missing, weak, diseased, or otherwise undesirable hills are done early in the spring before the first general pruning and cultivating operations are begun. The more common practice is to perform all three operations at about the same time.

Successful plantings have been made in the Pacific Coast States in the fall. Such plantings may be undertaken after the fall rains have begun but before the ground becomes too wet to work. Unless unusually cold weather follows, accompanied by alternate freezing and thawing, during which the cuttings are heaved out of the ground and injured by freezing or drying out, the practice is one that might be tried more extensively. If the cuttings take root properly without undue loss from rotting or from the other causes mentioned, maturity of the plants may be hastened and commercial yields secured sooner than with spring planting.

PLANTING

The common practice is to plant the cuttings or sets in rows an equal distance apart each way. In the older yards the hills are from 6½ to 7 feet apart. In more recently established yards the plants are set 8 feet apart. When set 6½ feet apart, there will be 1,031 hills to the acre; when set 7 feet apart, there will be 889 hills per acre. Where two horses or tractors are used in cultivating, the distance between rows is usually 8 feet, and only 680 hills per acre are required. In some of the irrigated yards on the better hop soils of the Pacific coast, the hills may be only 3¼ to 4 feet apart in the rows.

The methods of cultivating the hopyards necessitate straight rows. Two to four cuttings are usually set in each hill, but opinions differ on this point and practices vary. The preferred number to set is, in a measure, dependent on the system of training employed and the cost of "roots." The setting of an extra cutting is a precaution against losses due to vacant hills. A good method of setting the cuttings is to mark first the center of each hill with a small stake (fig. 5) to which are to be attached the strings on which the vines are to run. Another method is to make a hole with a spade at the location of the hill and to plant therein one or more cuttings, according to their quality.

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Cuttings, even of the common commercial varieties, cost up to $10 or more per thousand, depending on whether they are plentiful or scarce. Rooted sets of the same varieties are usually higher in price.

CULTIVATING

The cultivation practices in the various hop-growing sections differ according to seasonal needs, and the implements employed are largely a matter of the preference of individual growers.

Following harvest, after the old vines have been killed by frost they are usually cut off by hand just above the ground, raked into piles, and burned. Occasionally the vines are shredded by machinery, returned to the soil, and disked or plowed under in the fall. Sometimes they are allowed to remain attached in the field until spring, when they are either removed by hand or cut off with disk plows during the plowing operation that precedes pruning. Growers

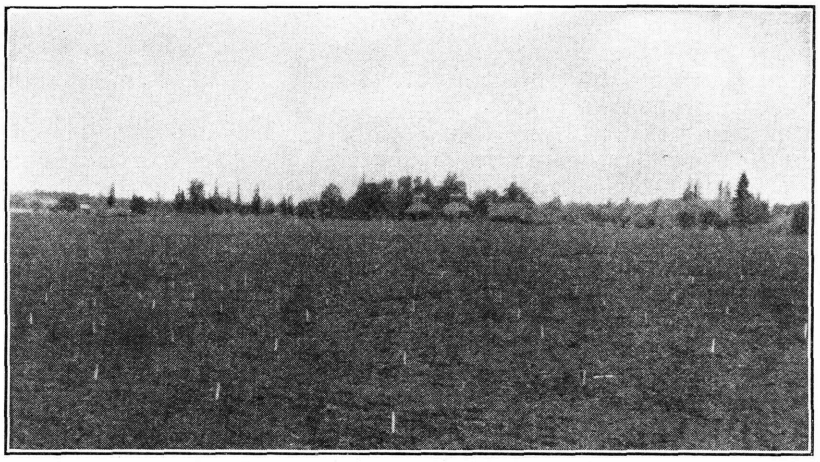

FIGURE 5.—Field staked for new planting

will have to use their own judgment regarding the advisability of cutting vines immediately following harvest, before they have been killed by frost (fig. 6). The practice is thought by some growers to injure the vines and reduce yields. There is, however, no conclusive experimental evidence available to support this opinion. In yards seriously infected with downy or powdery mildew or heavily infested with lice or red spider mites, cutting and burning of vines immediately after harvest would be a desirable control practice provided no damage resulted to the following year's crop.

The first cultivation operations are usually those described in connection with pruning (p. 11). In more extensive plantings the tractor has largely replaced horses, and disks are used more often than other types of plows. The careless use of rapidly drawn tractor-operated disk plows is responsible for much needless injury to crowns. Mechanically injured crowns are subject to root rots, and the life of the plantings is thereby often materially shortened. The amount of necessary annual replanting and the cost of production

are thereby increased because of the cost of replants, the labor of planting and care of the young plants, and the reduction in yields because of the high percentage of immature plants. Various types of harrows, rollers, and drags are used to develop and maintain a satisfactory condition of the soil as soon as possible after spring cultivation begins.

Thorough cultivation is important and should begin early and continue until the plants are well armed out. This is necessary not only to keep down the weeds, but also to prevent the topsoil from forming a crust and becoming hard, for when it is in this state the moisture of the subsoil rises to the surface and evaporates quickly. If small feeding roots are destroyed or seriously injured by late cultivation, growth will be checked and early ripening favored. The

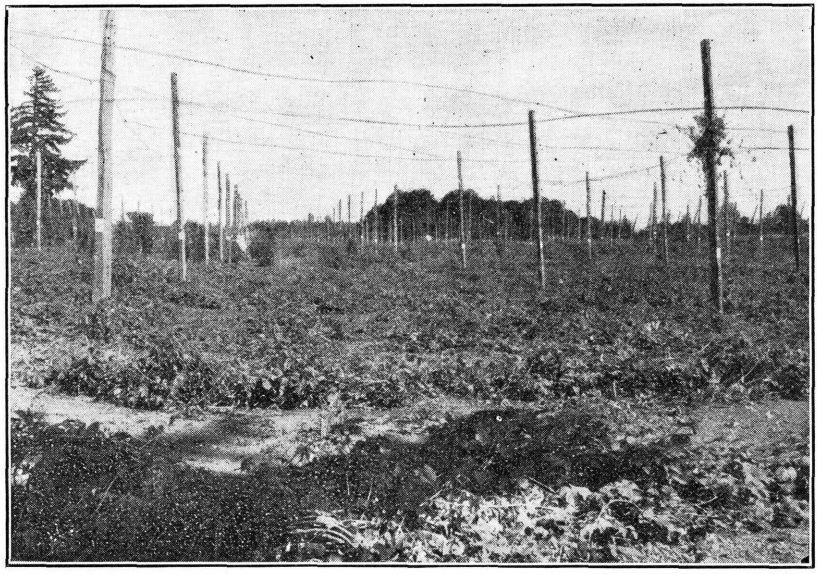

FIGURE 6.—View of the yard immediately after harvest, before vines have been cut.

existing soil conditions must determine the advisability of cultivating after the appearance of the feeding roots. If weeds are under control and the soil is not crusted, further cultivation is not only unnecessary but is apt to do more harm than good, especially late in the season. Cost of production can be materially reduced by rigid economy in cultivation. Many growers are inclined to cultivate more than necessary.

PRUNING

The excess shoots from the rootstock should be removed by pruning, thus favoring the development of a few strong vines. The rootstock itself also is pruned to an acceptable form at a suitable depth below the surface of the soil, and the formation of undesirable runners is retarded or suppressed. The working over of the ground incident to pruning also is an important part of cultivation. The

general practice is to prune early in the spring, the exact time being determined by the season and the locality.

A common practice is to draw four or five furrows with a small plow on each side of the row, turning the earth away from the hills. The yard is then cross-plowed in a similar manner, leaving each hill a small undisturbed square. A tractor-drawn disk plow is sometimes used to accomplish similar results. The earth is then hoed and grubbed away from the roots, and the superfluous roots and runners, together with an inch or two at the top of the root crown, are cut off, usually with a sharp knife. After pruning, the hoe is used to pull the soil back upon the hill, covering the rootstock to a depth of 2 or 3 inches. Occasionally the hills are left open after pruning and covered in the course of the next cultivation. Severe pruning by any method often results in root rots, and uneven pruning frequently causes the late development of the overpruned vines. In pruning, each plant should receive individual treatment according to its condition and state of development. The number and strength of the vines produced after pruning afford the best means of judging the correctness of the pruning and the soundness and vigor of the rootstock. There is reason to believe that if more attention were paid to pruning, much injury to the plants would be avoided with an appreciable reduction in the required amount of annual replanting. A substantial increase in the yield and quality of the crop would result.

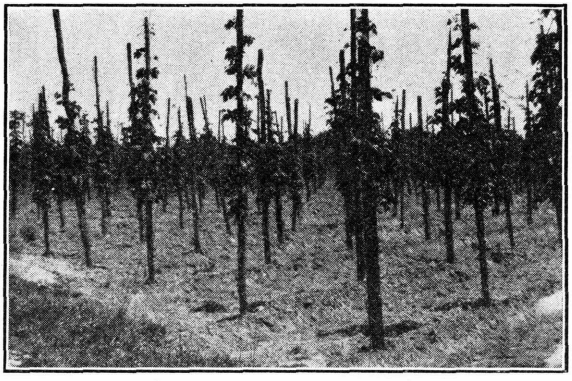

FIGURE 7.—A pole yard in Puyallup Valley, Wash.

TRELLISES

Hops may be grown on either poles or trellises, and while the use of hop poles has been largely discontinued (fig. 7), they are still in use in a few yards in coastal California, in New York, and in southwestern Washington.

For a permanent yard some form of the wire trellis shown in figure 8 will doubtless give the best satisfaction in most sections. The first cost may somewhat exceed that of the pole system; but the saving in labor, the advantages afforded in spraying, and the heavier crop obtained by this method have uniformly reduced the cost of hop production where poles have been replaced by wire trellises.

The wire trellis is constructed in many ways, but these may all be included in two general classes or types—the high and the low trellis.

The low trellis appears in several modifications. In one form (fig. 9) poles or stakes about 8 feet long are set at each hill. Wires are run over the tops of the poles the full length of the yard each way,

crossing at right angles. The vines are led up the poles or stakes and then find support on the wires. In many cases stout twine is

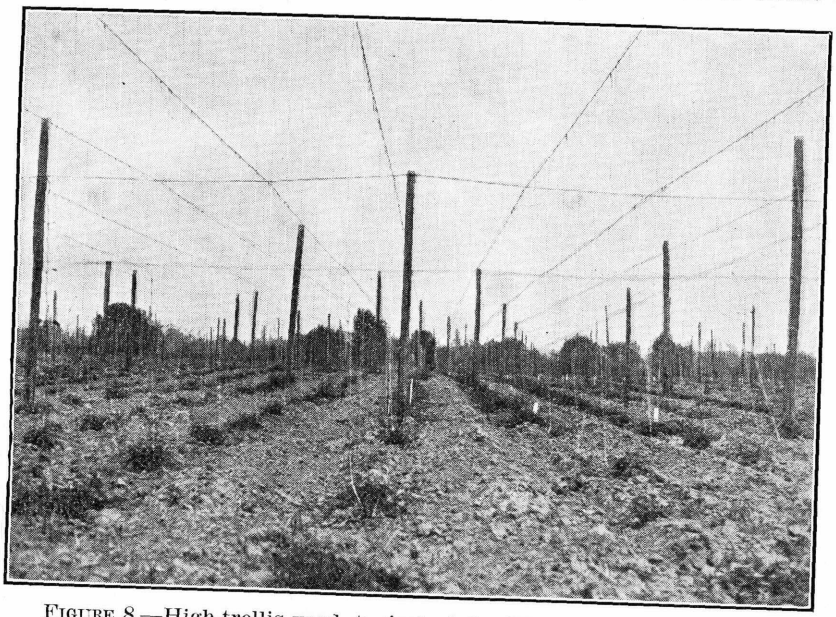

FIGURE 8.—High-trellis yard, typical of the Willamette Valley, Oreg.

used instead of wire, and in some instances the poles are set at every third hill.

A hopvine will not follow a horizontal support; therefore, when it reaches the wire or string of the low trellis it must be trained by

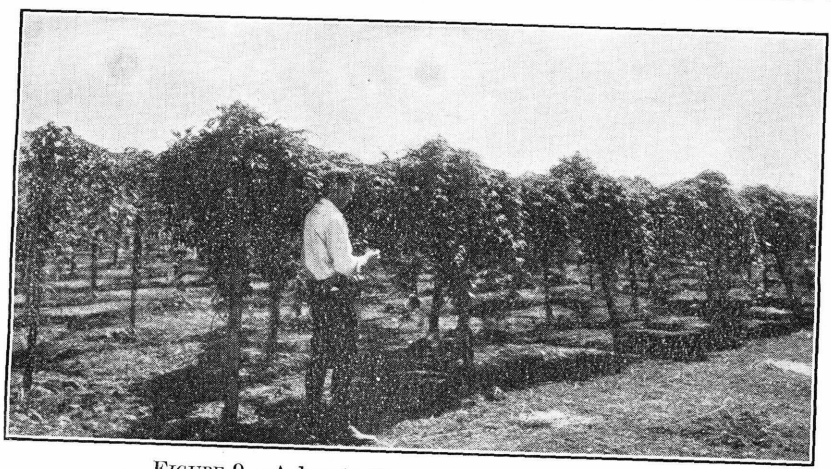

FIGURE 9.—A low-trellis yard near Ukiah, Calif.

hand. To avoid breakage, it is desirable, however, to train the tips of the vines down the wires even where the high-trellis system is used. Training sleds or carts are used for this purpose.

The high trellis is most widely used, and numerous variations in its construction are found. The fertility of the soil and possible damage from wind are prime factors in determining the height of the trellis, which ranges from 12 to 20 feet. Except in localities swept by strong winds, the high trellis is much more satisfactory than the low type. It is a permanent structure which gives easy access for teams to every part of the yard, the hops receive more uniform exposure to light and air and are consequently better developed, cultivation is not hampered so much by drooping arms as in the low-trellis system, and the hops can be readily sprayed even at picking time, when the worst attacks of lice are likely to occur.

A typical modern high-wire system consists essentially in setting posts at every sixth or seventh hill each way throughout the yard. Attached on or near the tops of these posts, wires are stretched across the yard each way at right angles (fig. 8). Posts are also set at the ends of the intervening rows, between which wires are stretched over the rows. These drop or string wires are held in place underneath the cross wires.

For posts, which may be of either split or sawed timber, hard pine, redwood, or red cedar—is used. The lower ends of many of the poles are treated with creosote to prevent or delay rotting. These posts are usually from 4 to 6 inches in diameter and up to 20 feet long. The end posts should not be less than 6 by 6 inches, but somewhat lighter timbers may be used for interior supports. The posts are set from 1½ to 2 feet in the ground, the interior ones upright, those in the outside rows inclining somewhat outward. At a distance of from 8 to 14 feet outward from the foot of each end post an anchor, made of a piece of timber 6 by 6 inches and 4 feet long, is buried at a depth of 4 to 6 feet, according to the tenacity of the soil. A strong guy wire is run from the top of the post and fastened securely to the anchor; or the string wire, or both string and guy wire, may be run over the tops of the end posts and down to the anchor.

To permit easier access to the field, posts are frequently placed at the ends of alternate rows only. The string wires of the rows without end posts are usually forked and fastened to the end posts on each side. For the principal or cross wires running across the field the short way and commonly fastened on or near the top of each post with heavy staples, No. 00 annealed iron wire is commonly used. These wires are stretched taut and fastened securely to anchors at each end. For the string wires, No. 8 annealed or galvanized-iron wires may be used. On the latest improved or drop-wire trellis (fig. 8) the string wires are held in place underneath the cross wire by short **S**-hooks made of No. 00 wire, which are fastened tightly to the cross wire. The lower end is left open so that at picking time the string wires may be unhooked and let down, thus bringing the hops within easy reach of the pickers.

STRINGING

Where the high-wire trellis is employed, cotton twine is used to form supports for the vines until they reach the wires. The strings usually consist of two portions knotted together; one, a piece 4 feet long having a breaking strength of 80 pounds, is attached to the

wire, and the other, a piece 15 feet long having a breaking strength of 20 pounds, is tied to a small stake set at the hill. The weaker portion is strong enough to support the vine until it reaches the stronger portion at the top. Hemp has been used for the top piece instead of cotton. In recent years twine made from other cheaper fibers has been employed with apparent satisfaction. Twines of different breaking strength are used. In young plantings particularly, for resets, and in some of the older yards with only moderately high trellises, unpieced strings of uniform strength are used.

The plan used for fastening the strings to the wires in trellis yards where the drop-wire system is used is simply to unhook and lower the string wire, to which the strings may then be attached by the workmen while standing on the ground. The strings, which are cut to the desired lengths and knotted in advance, are fastened to the

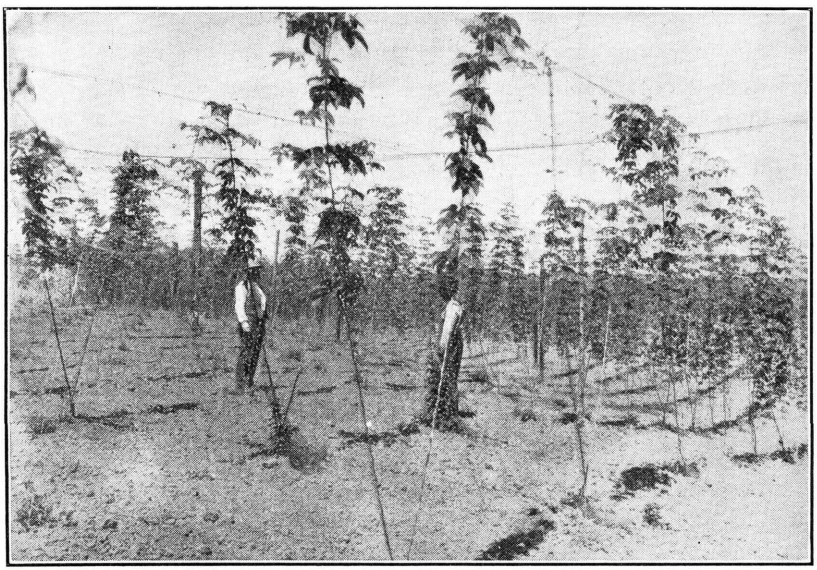

FIGURE 10.—Yard "stripped" and "suckered," showing method of stringing.

wires about 20 inches from a point on the wire directly over the center of each hill. Usually two strings are used for each hill; and when all have been fastened to the wire, it is again hooked up in place on the cross wires (fig. 10). For new plantings or replants in older yards only one string is used. Frequently three strings are used, all attached to the same drop wire (fig. 2).

Variations of the more common methods of stringing are employed in different hop-growing sections. In the Yakima Valley, strings are usually tied to the pegs first and then to the wires without the latter being let down. A common practice in this section also is to run strings across the drop wires at right angles to the strings that lead down to the stakes at each plant. Training sleds or carts are employed in these operations. This practice provides additional support for the cone-bearing laterals and results in the formation of

an arbor which, while it may increase yields, is objectionable because it shades the vines below and provides conditions favorable for the development of lice and red spider mites and makes effective spraying for the control of these pests very difficult.

In some sections of California three or four strings may be used for each hill. In such yards the drop wire is strung between the rows of plants and the strings from the plants are attached to two opposite drop wires instead of to one.

Another plan for stringing the yard involves the use of a "trellis wagon," or sled having a platform of such elevation that the workmen thereon may move about freely beneath the wires while attaching the strings. The wagon follows the string wires across the field. Two or three men on the wagon will put the strings on two wires as fast as the team can walk. Four men following the wagon fasten the ends of the strings to small stakes set in the ground at each hill.

TRAINING

When the young vines are about 2 feet long training is begun. The vines desired are selected in each hill, and the remainder are cut off. Where the stand is uneven, it may be well to cut off the whole field and wait for the second set of vines. However, vines that may be inferior at first sometimes develop a vigorous growth after they have reached a length of 4 or 5 feet. As a general rule, in light-producing sections it is customary to train the first vines; in heavy-producing sections the second- or later-crop vines are chosen. This practice of training the first vines, although not always followed, is used in the light-producing sections because of a desire to provide the vines with as long a growing season as possible, as they are apt to be less vigorous than those in heavy-producing sections. Choice of later crops of vines in heavy-producing sections results in sufficiently vigorous vine growth in a minimum period of time. Where downy mildew is a factor, early infections may be avoided by training the vines during weather less favorable to the development and spread of the disease. From one to three vines are usually trained to each string, care being taken to twine them in a clockwise direction about the string to insure their climbing and to prevent them from unwinding.

It has been shown that under certain conditions the yield per hill is directly proportional to the number of vines trained. Except on land that is very heavily cropped, better results should follow when at least six vines to each hill are trained.

In trellis yards, when the vines have nearly reached the drop wires, the strings are tied together about 4 feet from the ground to provide an unobstructed passageway between the rows.

As soon as the desired number of vines are trained, it is desirable to remove carefully the lowest pairs of leaves to prevent the spread of downy mildew. As soon as the vines have reached the drop wires, all side arms and leaves are removed from the vines below the point at which the strings are tied together. This practice, known locally as "stripping," should be employed with care. Many young vines are unduly checked in growth by too severe stripping. If vines are stripped too high, a "top crop" results and yields are reduced. Stripping wounds at the base of the vines may serve as a point of

entry for certain diseases and often so weaken the vines that they may crack or break off in midseason in windy localities. All suckers are removed from around the bases of the plants. This practice is known locally as suckering. Both stripping and suckering are primarily employed to force the growth into the selected shoots (fig. 10). Incidentally, these are important aids in the suppression of the mildews and such pests as lice and red spider mites.

HARVESTING

TIME TO PICK

Hops should be picked when fully mature, but this date varies with the locality, seasonal conditions, and varieties grown. Some varieties mature earlier than others and hence must be picked earlier. The date of maturity of different varieties varies according to locality and seasonal conditions but is usually fairly constant from season to season in any one locality. The ripeness of the hops largely determines their quality. Frequently, particularly when the acreage is large, growers begin picking the crop before it is ripe because of the fear of some loss because of overripeness, or damage from red spider mites, mildews, or sooty mold. Unripe or immature hops are deep green in color, soft and pliable, and lack resiliency or elasticity. The cones are smaller, and they contain more moisture and hence lose more weight on drying than those of mature hops; therefore they are somewhat more difficult to dry on the kilns. The lupulin in unripe hops is not fully developed and contains less resins and essential oil. Thus when hops are picked too early the grower is apt to lose in the weight and the consumer in the quality of the hops. Ripe or fully matured hops possess a full agreeable aroma and contain their maximum content of desirable constituents on which their brewing value depends. They are usually bright yellowish green in color, sticky, crisp, or papery to the touch, and noticeably resilient. Seeds, if present in ripe hops, are hard and purplish red in color.

By careful examination of the hops in the field the grower can readily determine when the crop is in prime condition for harvesting. It should be the aim of all growers to pick hops at the peak of their quality if the exacting demands of the trade are to be met. It is often impossible to pick the whole crop in its ripest condition in the course of a few days because of labor shortage or the limited capacity of most drying kilns. The quantity picked each day must be regulated to conform to the facilities available for drying and handling the crop. If more hops are picked than can be put upon the kilns and dried without delay, they undergo heating, and as a result are seriously damaged in quality or lost entirely. Hops do not always ripen evenly in a large field, because of variable soil and moisture conditions. By frequent and careful examination of the crop, however, it is sometimes possible to pick from portions of the field showing the most desirable degree of ripeness. There is less danger of loss to the grower if picking is prolonged after maturity than if begun too early. Hops after reaching full maturity have been found to maintain their high quality for 2 or 3 weeks without noticeable change in their constituents.

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Picking hops that are extremely overripe is not recommended. Overripeness causes a darkening of the yellow color of the cones, from which the bracts shatter easily, and this results in a decrease in the desirable resins. Slight overripeness, on the other hand, is not greatly detrimental to quality even though the cones darken slightly.

In some sections both early and late varieties are grown, which aids the grower with limited facilities in handling the crop and is an advantage to the pickers by prolonging the period of their employment.

Because of the influence of maturity on quality, growers should recognize the importance of the proper time of picking for the production of hops of the highest commercial value.

FIGURE 11.—Picking hops by hand.

It is important, in picking hops, that the quantity of leaves and stems be reduced to a minimum, because the presence of these extraneous substances not only renders them unsightly but also reduces their quality and market value.

METHODS OF PICKING

Hops are picked commercially either by hand or machine, but hand picking is most generally employed (fig. 11). Unless hand picking is carefully supervised the hops are likely to contain considerable quantities of leaves and stems, because these substances add weight, and pickers are usually paid on a pound basis. In some producing sections where picking is conducted under strict supervision and where higher prices are paid to pickers, hand-picked hops now contain a considerably smaller amount of leaves and stems than formerly.

Stationary hop-picking machines (fig. 12) have been successfully used by a few California growers for a number of years. Recent improvement in the machines has made it possible to pick hops by this method practically free from leaves and stems. Analyses show that less leaves and stems are generally contained in machine-picked than in hand-picked hops. However, when picked by hand with proper care and supervision, they frequently compare favorably in cleanliness with those picked by machine. A fair working capacity of a stationary hop-picking machine such as is used in California is approximately 6½ acres per day. Portable hop-picking machines (fig. 13) have recently been developed that may greatly extend the

FIGURE 12.—Stationary hop-picking machine showing vines entering machine.

advantages of mechanical picking to all of the important hop-growing sections of the United States.

The trade, at present, is inclined to favor clean-picked hops because of the possible detrimental effect on the flavor and taste of brewed beverages caused by the undesirable extractive matter contained in the leaves and stems. For this reason growers should endeavor to pick hops as cleanly as possible in order to raise their standard of quality for brewing purposes.

DRYING

Drying and curing are the next important steps in the preparation of hops for the market. Both must be carefully conducted and supervised for the production of hops of high quality. Freshly picked hops contain from 65 to 80 percent of moisture, depending on the variety and the degree of ripeness; and this moisture must be

reduced to approximately 12 percent, otherwise heating will take place while the hops are being stored preparatory to baling. Such heating is likely to cause a brownish color and a change in the desirable resinous constituents and especially in the aroma or essential oil, resulting in a sour or musty odor.

In practical drying the temperature must not be too high. In taking the temperature, it is essential that the thermometer be placed just below the drying floor where the heat is greatest. With low drying temperatures there is less danger of unfavorable effect on color, aroma, and resinous constituents of the hops. It is possible to dry hops successfully by forcing through them a large volume of air at low temperatures. In certain sections where the atmospheric temperatures are commonly above 100° F. the crop

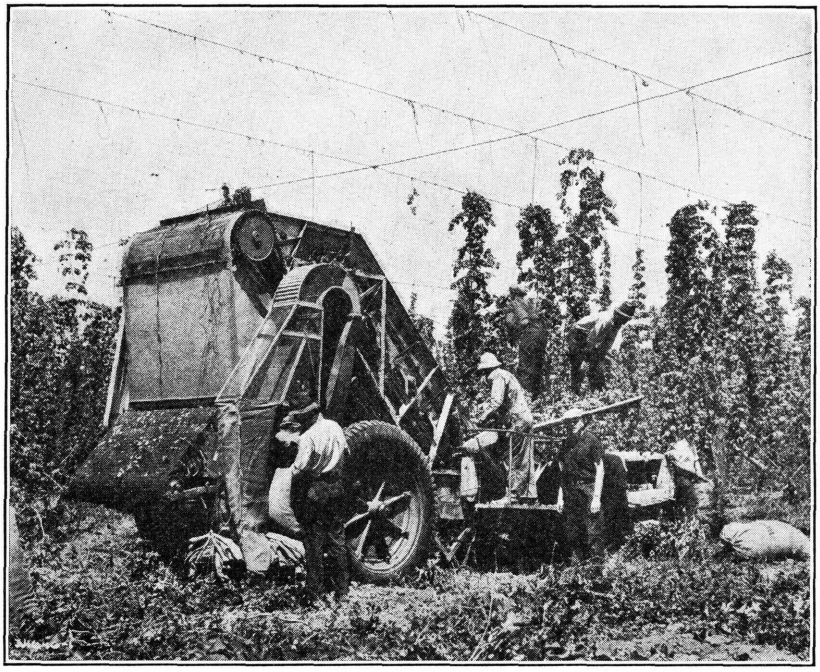

FIGURE 13.—Portable hop-picking machine.

is dried at the temperature of the natural air in 18 to 20 hours by the use of such forced draft. This is possible only in sections where the outside air is extremely dry. In the more humid sections temperatures of 145° to 150° are frequently necessary and have been found satisfactory. The weather conditions prevailing in a locality will therefore largely determine the temperature at which drying may be best accomplished.

When temperatures considerably above 165° F. are used, the hops can be dried in 10 to 12 hours; but under such extreme conditions they are apt to become darker, the lupulin is rendered inferior, and they become fluffy and shatter easily and possess a burnt or scorched aroma, making them less desirable to the trade.

There are several kinds of kilns on the market which differ mainly with respect to construction. However, only two are in general use, the natural-draft stove kiln, in which the hops are heated by a stove or furnace placed under the floor, and the forced-draft kiln, in which a current of heated air from the outside is forced in or drawn through by a fan.

The natural-draft stove kiln consists essentially of a furnace room heated by a large stove or furnace, and a drying room immediately overhead, into which the heated air from the furnace passes through cracks in the floor. The stove is commonly placed at one side of the furnace room and so arranged that the firing can be done from the outside. The building is usually a tight frame structure with a four-sided roof carried up at one-half or two-thirds pitch. At the top is a square opening over which is built the ventilator or cupola.

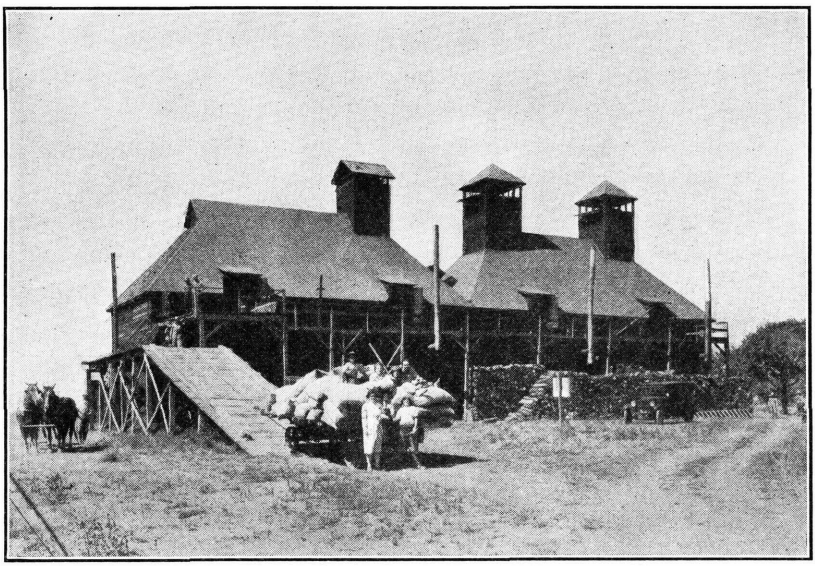

FIGURE 14.—Natural-draft stove kiln in western Oregon, showing loading facilities.

Two, or sometimes four, shutters, hinged to the sides of the cupola at the top, are fittted with ropes and pulleys, by means of which they may be opened and closed. The drying floor is constructed of slats about 1 inch thick and 1 to 2 inches wide, carefully spaced about 1 inch apart. A kiln cloth or carpet of 8- to 10-ounce jute, similar in quality to the ordinary barley sack, is stretched over the slats. Air is admitted through openings in the outside walls close to the ground. These draft openings are provided with shutters, which are closed on the windward side to prevent uneven drying when strong winds are blowing. The drying floor should never be less than 20 feet above the ground on account of the danger of scorching the hops.

On a level with the drying floor at one side of the kiln is a platform from which the green hops are transferred to the drying floor. When possible the kiln is erected on sloping ground, so that the hops may be unloaded thereon from wagons, which approach the kiln on

a driveway formed by a slight embankment or on an inclined wooden driveway (fig. 14). Another practice is to bring the hops from wagons on the ground to the platform by means of an elevator or conveyor. A battery of natural-draft stove kilns is shown in figure 15.

A newer type of stove kiln, or the forced-draft kiln, equipped with a vertical tandem fan in the cupola which makes possible more rapid drying in shorter periods at lower temperatures, is shown in figure 16. Horizontal fans are also employed. Many of the older natural-draft dryers are being reconstructed for use with cupola fans. In an improved method of drying with a forced draft that has been used successfully on the Pacific coast during the last few years a fan is used to drive the air through the hops from below.

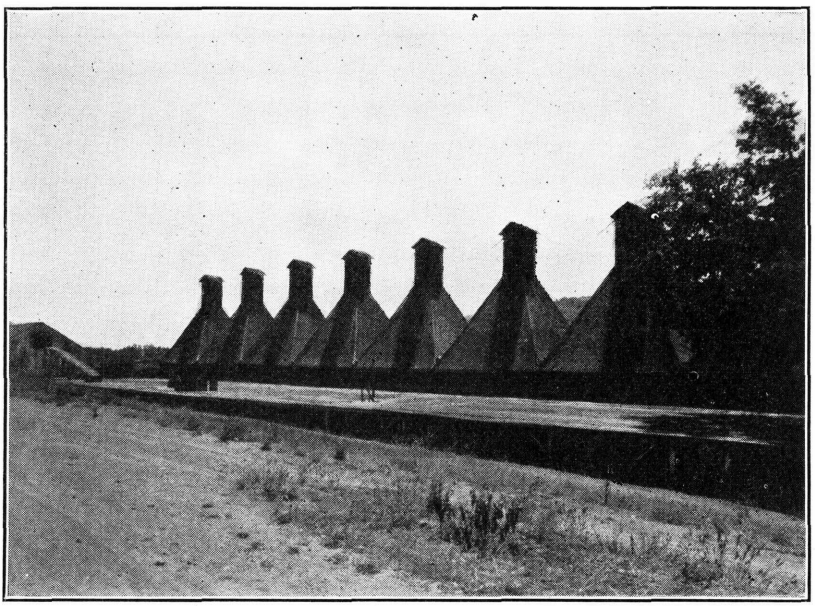

FIGURE 15.—Battery of natural-draft stove kilns in coastal California. Note loading platform and sidehill location.

The hops should be spread out evenly and loosely to a depth of 20 to 24 inches in natural-draft, and 30 to 36 inches in forced-draft kilns. In an uneven layer the heat will break through first in the thinner places where the hops quickly become dry, while in the thicker portions they remain damp. If they are trampled or otherwise packed together on the floor the heat will not readily pass through them and the drying will not be uniform.

As soon as the hops are laid on the floor the fires are started. In operating the kiln the heat is gradually brought up to the desired point. In 6 to 12 hours the hops will have become heated throughout and sufficient moisture will have been driven off so that the hot air will readily pass through them. Until this point is reached the temperature must be closely watched, as too rapid firing at first will cause the lower layers to scorch.

During the course of drying in natural-draft kilns sufficient ventilation must be provided to carry off the moisture without at the same time cooling the sides of the kiln and the top of the hops enough to cause the moisture to be condensed, resulting in "stewing." This may be prevented by keeping the draft boards partly open at all times and the temperature below 140° F. until the heat breaks through the hops. If the sloping roof is ceiled, thus producing a stronger draft, the kiln operates more efficiently.

No definite rule has yet been given for determining when hops are sufficiently dried. The condition in which they may be safely removed from the kilns can at present be told only by experience. The amount of drying will vary from day to day, being dependent on weather conditions and the ripeness of the hops. In general,

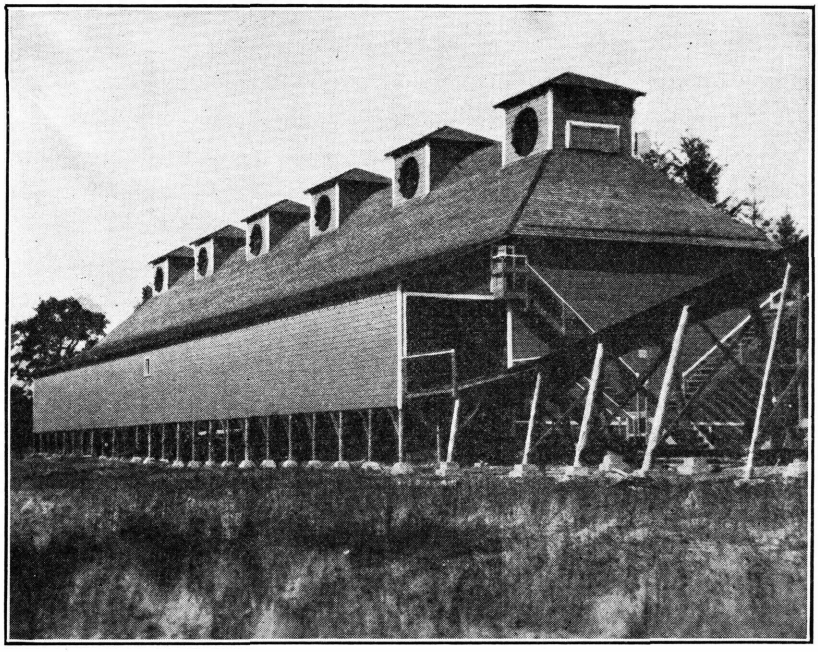

FIGURE 16.—Stove-type kiln equipped with cupola fans.

drying should continue until nearly all the stems or cores are shriveled, but are still soft and pliable. The thin leaflike portions of the hop usually become dry enough to break readily by the time the stems are dried sufficiently to make safe the removal of the hops from the kiln. Many careful dryers make a regular practice of gradually closing the ventilators as drying proceeds and finish with them tightly closed. This practice makes possible the retention of heat in otherwise inadequate kilns. Overdrying may be partly offset by opening all the doors of the kiln and letting the hops cool for about an hour, as by this process they absorb moisture from the air and become less brittle.

Formerly sulfuring was almost universally resorted to in order to produce hops of a uniform golden-yellow color. The usual prac-

tice followed was to burn the sulfur beneath the kiln floor at the rate of 1 to 4 pounds for 100 pounds of undried hops. Besides its bleaching effect it was thought that it accelerated the drying and retarded the deterioration of certain of the desirable chemical constituents and thus improved the keeping quality of the hops. Because the trade at present prefers hops with a green color, the use of sulfur has been generally discontinued. A few growers still use it but in much smaller proportions. Unless the sulfur used is of the highest purity, certain of the impurities may injure the quality of the hops. Whether sulfuring is of any real value for the purposes mentioned when used in small quantities is problematical, and its effect on the soft resins and aromatic constituents needs further investigation.

CURING

After the hops have reached the proper degree of dryness they are removed from the drying kiln to the cooling house or cooler where they are piled in huge heaps and allowed to stand for 10 days to 2 weeks to undergo a curing or sweating process. During this period, the moisture content, which is not always uniform in each batch removed from the kiln, is equalized, and the hops become tough and pliable and acquire a finer aroma and better appearance.

The building used for curing is now generally detached from the dry kiln and placed at a distance of 100 to 200 feet as a safeguard against fire. The building should be of tight construction, especially in humid regions, to prevent the loose hops from absorbing too much moisture from the air.

The kiln is usually connected with the cooler by an elevated tramway, over which is run a large car carrying the freshly dried hops. The sides of the car are hinged so as to swing open from the sloping bottom, allowing the hops to be readily removed with little handling. In some kilns provision is made at one side of the drying floor to permit the hops to be readily shoved off into the hop car, which is brought alongside the kiln with its top just below the level of the floor; in others, the cooler is connected with the kiln, and the hops are removed from the kiln floor and shoved directly into the cooler without the use of a car.

After being placed in the cooler, the hops should be handled as little as possible to prevent undue breakage, which affects their appearance and results in a loss of lupulin. Because of the importance of the curing process, which is the last step before baling, great care and good judgment are necessary for proper handling in the cooler in order to produce hops of highest quality.

BALING AND STORING

After the hops have been properly cured during storage in the cooler for a week or 10 days and have become sufficiently pliable to prevent undue breakage on handling, they are ready to be compressed into bales. They may be left in bulk for many weeks and will suffer little injury if the storehouse is tightly closed to exclude atmospheric moisture. Careful examination of the hops should be made before baling, so as to determine whether they contain an excessive moisture

content. The strig to which the bracts are attached and which contains most of the moisture of the hop should be pliable and tough but should not be noticeably moist. If too much moisture is present, hops are apt to heat in the bale, causing damage to both color and aroma.

The dimensions and cubical contents of commercial bales vary widely because of the lack of uniformity in the dimensions of baling presses, as well as in the pressure to which the hops are subjected. A bale measuring 4¾ by 2½ by 1½ feet contains approximately 18 cubic feet of hops and weighs about 195 pounds net. In this type of bale, commonly used for domestic marketing, the hops are compressed to approximately 11 pounds per cubic foot. Even though dimensions of bales vary considerably, the weight of hops per bale remains fairly constant. Frequently for export purposes, in order to save space on vessels, the hops are compressed to as much as 20 to 24 pounds per cubic foot. Such hops are termed "recompressed," i. e., they are compressed to the desired density from the regular commercial sized bale and rewrapped in heavy burlap. Moreover, for such shipment, hops are also sometimes compressed to a density of about 43 pounds per cubic foot into cakes weighing 8 pounds each and measuring 16 by 16 by 1¼ inches. The cakes are subsequently packed in tin-lined wooden cases and hermetically sealed by soldering in order to prevent possible damage in transit from moisture or water. Standardization of bale dimensions and rate of compression is perhaps worthy of more consideration by the growers. Freight and storage rates might be reduced thereby, and the quality of hops retained over longer periods in storage.

For handling large crops of hops, some form of power-baling presses, which differ widely in design, are always employed. Presses operated by one or two horses are still in use. Some are operated by gasoline or electric motors. The same general principle is involved in the operation of all presses regardless of type.

In baling hops, the practice of trampling them, to facilitate filling the box in which the bale is formed, should be discontinued, as too many of the hops are broken thereby. While filling the box, the corners of the bale may be slightly tamped, but even this should be carefully done, especially if the hops are dry. Careful handling is urged, as the hops are often broken and crushed on the floor before being baled, and this results in a loss of lupulin and gives them a bad appearance.

Hops are baled in jute bagging, 16 threads or less to the inch. About 5 running yards of bagging are required for each bale. This weighs from 7½ to 10 pounds, and for it 5 pounds tare is allowed in selling.

Bales should be of even weight, 185 to 210 pounds net. It is important that the hops and baling cloth be kept clean and that sweepings be kept out of the bales. Considerable complaint is received about hops discolored by baler grease. A good, clean, odorless oil (crystal oil) should therefore be used.

Because baled hops are usually handled by hooks when being stored and transported, it is important that the bales be properly and securely sewed to prevent damage. Eight- or ten-ply twine is used in sewing the bales. Starting at the extreme ends of the bale

and using a lock stitch not more than 3 inches long, the needle is run through the cloth over the twine. The twine is then looped over the needle (half hitch) and pulled tight. Properly sewed bales should not expose any of the hops at the seams.

Hops undergo gradual changes in their constituents while in the bale, depending upon the conditions of storage. Growers often hold baled hops in storage for considerable periods, usually at comparatively high temperature. Under such conditions, the desirable bitter soft resins and the essential oil are easily oxidized to hard resins that are devoid of brewing value, and a decline in the market value of hops so held is therefore likely to result. Hops that have been kept in such storage as long as 4 years have at times entered trade channels with little regard for their quality.

Because of the cost of cold storage or the lack of such facilities, growers usually store their hops in warehouses at temperatures that fluctuate with the season. Besides the general deterioration referred to, a loss in moisture frequently takes place that results in a further loss to the grower. In the absence of cold storage, which is acknowledged to be the best means of protecting hops against deterioration, it is recommended that hops be stored in cool warehouses at temperatures kept as low and as constant as possible. The necessity of proper baling and subsequent storage of hops to protect their quality is emphasized, and careful attention to this phase of their handling should benefit the grower and consumer alike.

DISEASES AND THEIR CONTROL

The diseases to which hops are subject in the United States, although not numerous, are of decided economic importance. Efforts to control them materially increase the cost of production. Seasonal and environmental conditions favorable to their development and spread may result in partial or total loss of the crop. Even though a crop is harvested, the quality may be adversely affected, and, if sold at all, the profit to the grower may be definitely reduced. In some sections, plantings may become so badly diseased as to render locally available planting stock unfit for use and make the maintenance of profitable yields in available yards impossible.

The diseases of hops with which growers are most familiar and which are of greatest economic importance are downy mildew, sooty mold, root rots, several of the virus diseases, powdery mildew, and crown gall.

DOWNY MILDEW

All commercial varieties of hops in the United States are subject to serious damage from downy mildew. None of the many introduced varieties is immune. The disease has been found in all of the commercial hop-growing States and in practically all hop-growing sections in those States that have been thoroughly surveyed. In some sections of California and Washington, where weather conditions are unfavorable for its development, it is less prevalent and of less importance.

A part or all of the shoots arising from an infected hill may be diseased (fig. 17). Badly infected shoots are unable to climb and are severely checked in growth. Healthy side arms may have to

be trained up or new shoots from the crown may have to be used to secure a stand of vines. This practice may delay the ripening and subject the cones to infection before they can be harvested (fig. 18). Infections on the vines (fig. 19) kill many of the buds from which side arms develop, and the attached leaves usually become infected also.

For the suppression of "spiked" shoots at the crowns, the use of calcium cyanamide has been found effective in most sections. Two ounces of the granular form of the material should be scattered over the crowns in a circle approximately 2 feet in diameter as early in

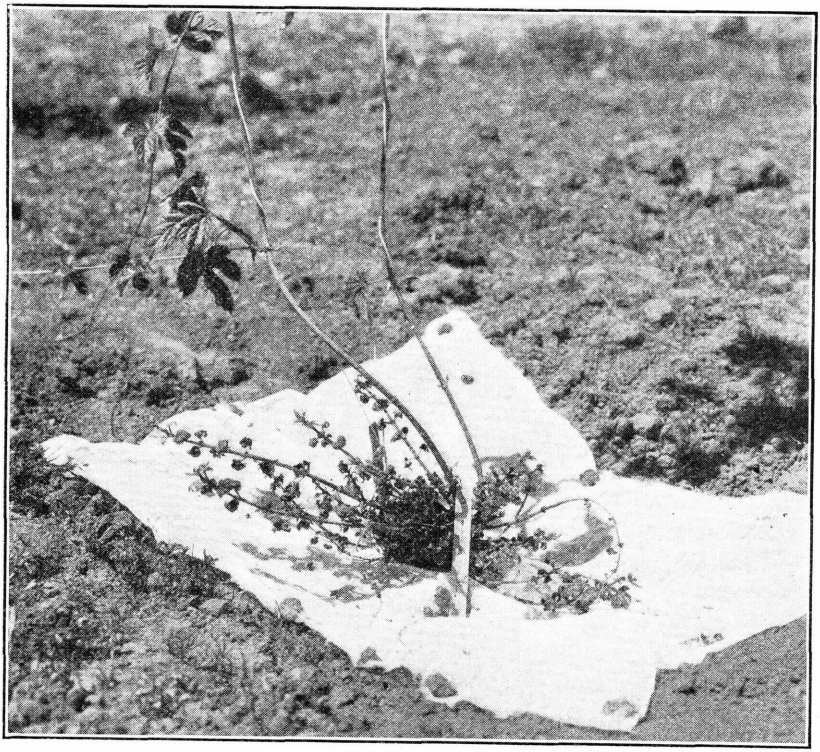

FIGURE 17.—Plant infected with downy mildew. Note the two healthy vines arising from among a cluster of "spiked" shoots.

the spring as weather conditions will permit and before the vines are hoed. No application should be made to replants.

Escaped hops growing on guy wires, in fence rows, or on ditch banks surrounding cultivated yards should be removed. These vines may become diseased early in the spring and remain a source of infection throughout the growing season.

Prompt and careful removal of the lower leaves at training time is a desirable control practice. The usual practices of suckering and stripping also assist materially in keeping down serious infection. "Spikes" that appear at any points on the vines should be removed and, if possible, carried from the yard in tight containers and burned.

As soon as vines are strung, fungicides in either dust or liquid form should be applied. Further applications should be made as

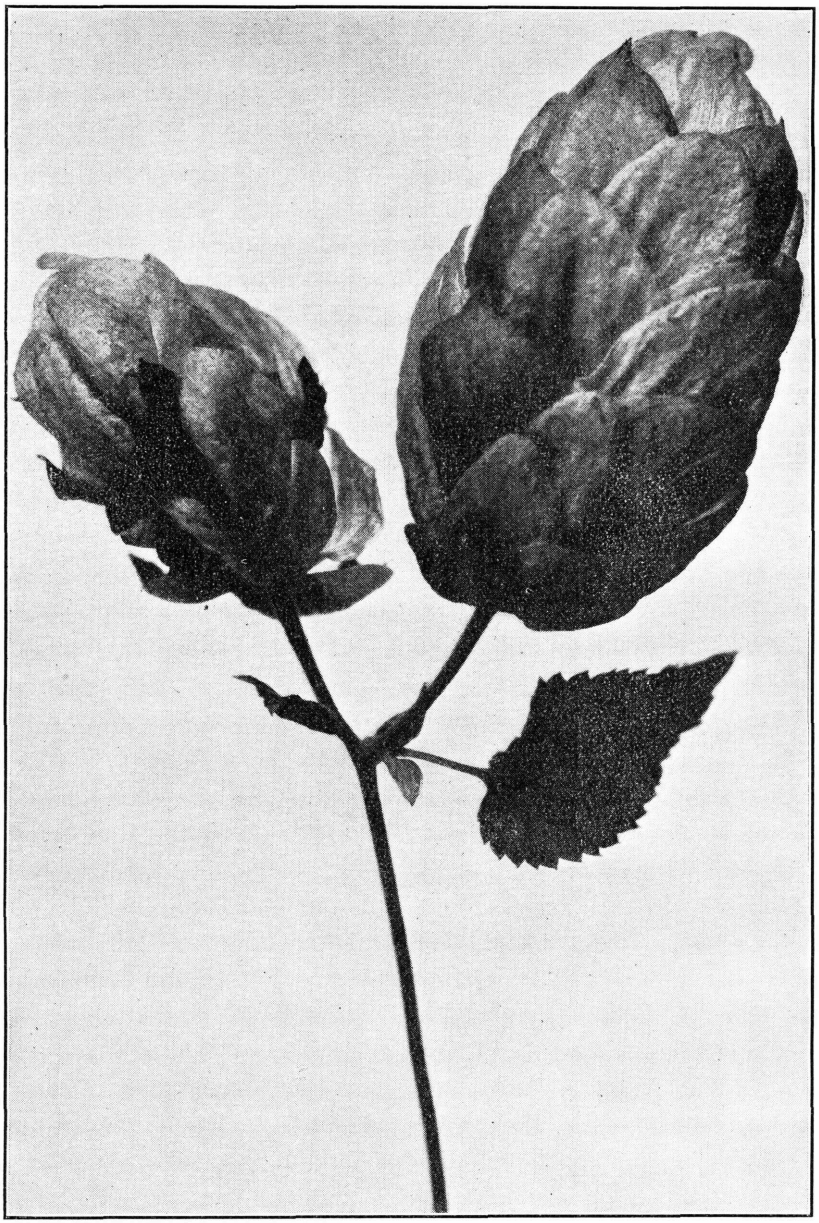

FIGURE 18.—Cone on left damaged by downy mildew. Normal cone on right.

needed. Hand dusters and pilot rods for spraying may be used at the first application. Care should be taken to cover all parts of the

vines, particularly the under sides of the leaves. In dusting, a copper-lime dust, consisting of 1 part of monohydrated copper sulfate to 10 parts of finely divided hydrated lime, may be used.

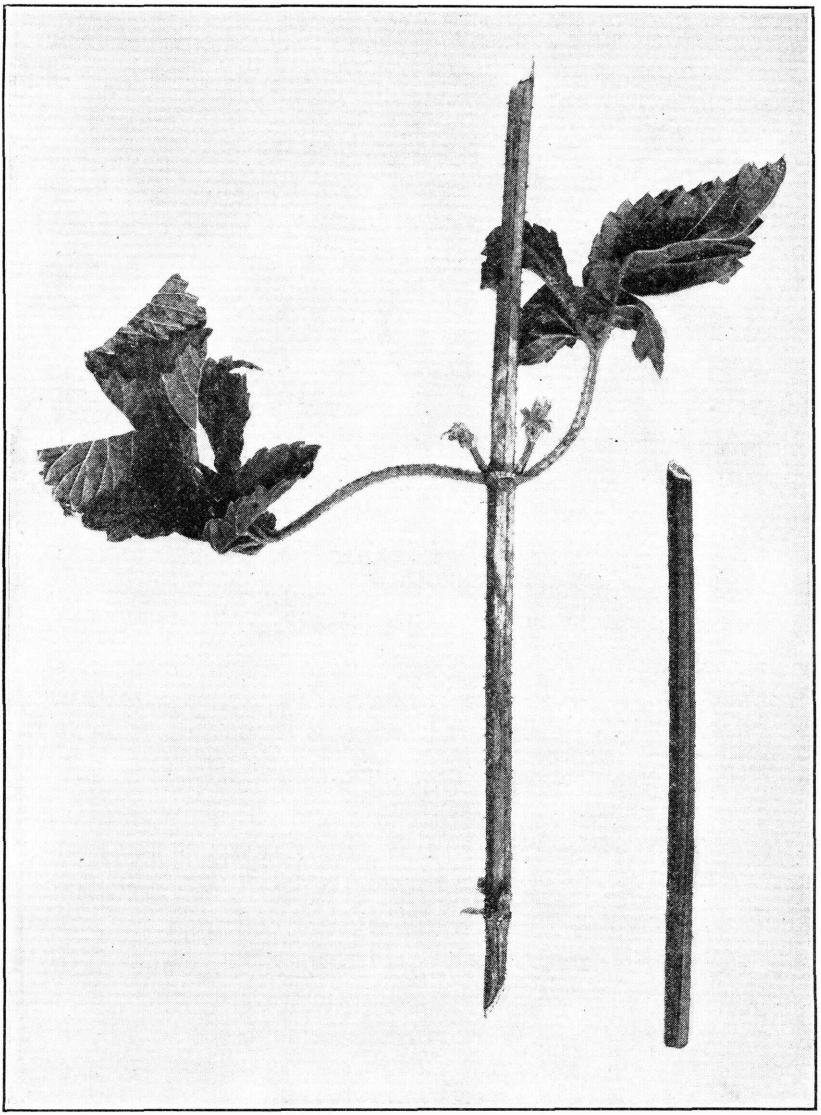

FIGURE 19.—Vine infected by downy mildew. Note discoloration and blighted buds. Healthy stem at right.

If liquid sprays are used, a 4–4–50 formula consisting of 4 pounds of zinc sulfate and 4 pounds of hydrated lime to 50 gallons of water is recommended. Not more than 1 quart of rosin-soap spreader

should be added. Thorough coverage of vines with liquid sprays is necessary, as it is when dusts are used.

SOOTY MOLD

Sooty mold is responsible for serious annual losses in all hop-growing sections of the United States. The fungus causing the disease grows on the honeydew excreted by aphids. All aerial portions of the vine may show the sooty-black discoloration. The most serious situation arises when aphids penetrate the cones; this is followed by the appearance of mold in the cones (fig. 20), where its presence

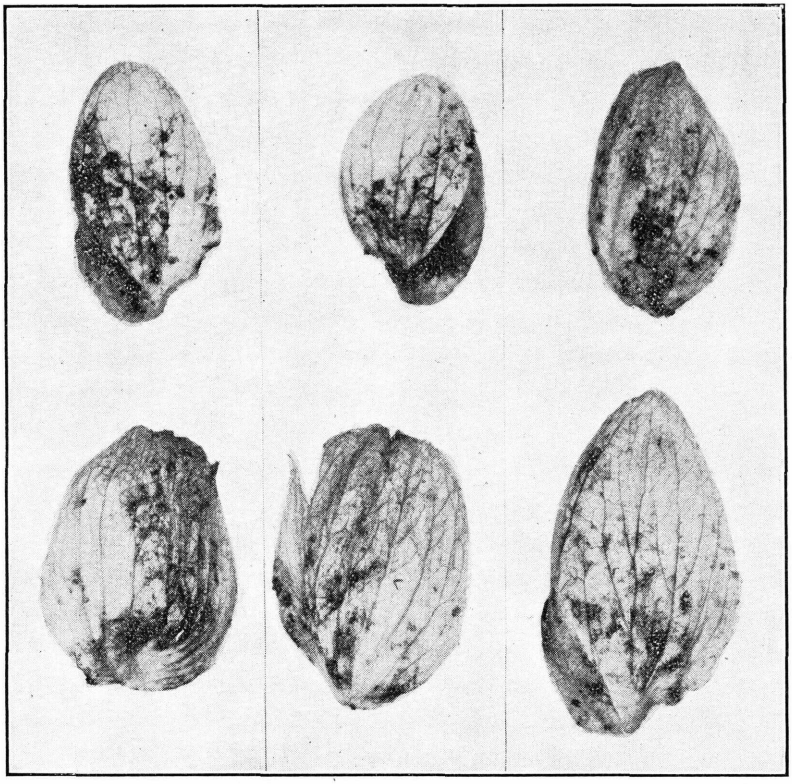

FIGURE 20.—Sooty mold growing on individual petals of a hop cone.

is easily detected in the dried samples. Moldy hops, if they can be sold at all, bring lower returns to growers, as they are apt to impart an undesirable flavor to the beer in which they are used.

No direct control measures are advocated. The most effective means of reducing losses from this disease is to control infestations of aphids before honeydew appears in any quantity.

ROOT ROTS

Root rots are usually associated with mechanical injuries to the crowns brought about by pruning and other cultural operations.

They result in the loss of newly planted cuttings and the gradual weakening and eventual death of older plants. They are usually characterized by a dry rot accompanied by a brownish or black discoloration of the diseased tissues. No direct control measures can be employed. Only healthy uninjured cuttings should be used in planting. Care in the pruning and cultivation of well-established plants to avoid undue injury will help to prevent serious losses.

VIRUS DISEASES

In all probability a number of the virus diseases that have been reported as affecting hops are responsible for appreciable damage in several of the hop-growing sections of the United States. Many abnormal plant types have been noted, and local names, more or less descriptive of the disease symptoms, have been applied.

Although present knowledge of the virus diseases, as regards their positive identification, distribution, effects on different varieties, method of spread, and means of control, is incomplete, it is known that some of them are potential menaces to profitable hop production. Affected plants should be removed promptly. Care should be taken not to take cuttings from diseased plants. Varieties known to be carriers of these diseases should not be introduced into plantings otherwise healthy.

POWDERY MILDEW

Powdery mildew is confined largely to New York. It attacks all above-ground portions of the vine (fig. 21), seriously affecting the normal development of the cones. In years favorable to its development and spread serious crop losses are experienced by growers who do not apply recommended control measures. Burning of badly mildewed vines in the fall and early spring training will assist in the control of this disease. Dusting with sulfur as soon as the mildew appears has given satisfactory control. Sulfur sprays may be used if preferred. The number of applications necessary will depend on the weather during the growing season. Wet weather favors the spread of the disease.

CROWN GALL

Although present in all sections of the United States where hops are grown, crown gall is only of minor economic importance. All commercial varieties of hops may become infected. The bacteria that cause the disease are spread from diseased to healthy plants by pruning and other cultural operations. When present on mature plants in sufficient amounts seriously to reduce their vigor or productiveness it can be combated effectively only by complete removal of the affected plants. Care should be taken to avoid the use of diseased planting stock.

INSECT PESTS AND THEIR CONTROL

Hops are subject to attack by a large number of insect and other pests. Among the more common insect pests are the hop aphid (*Phorodon humuli* Schr.), common red spider (*Tetranychus telarius* Linn.), western spotted cucumber beetle (*Diabrotica soror* Lec.),

onion thrips (*Thrips tabaci* Lind.), western flower thrips (*Frankliniella moultoni* Hood), omnivorous leaf tier, usually known as strawberry fruitworm (*Cnephasia longana* Haw.), hop-plant borer

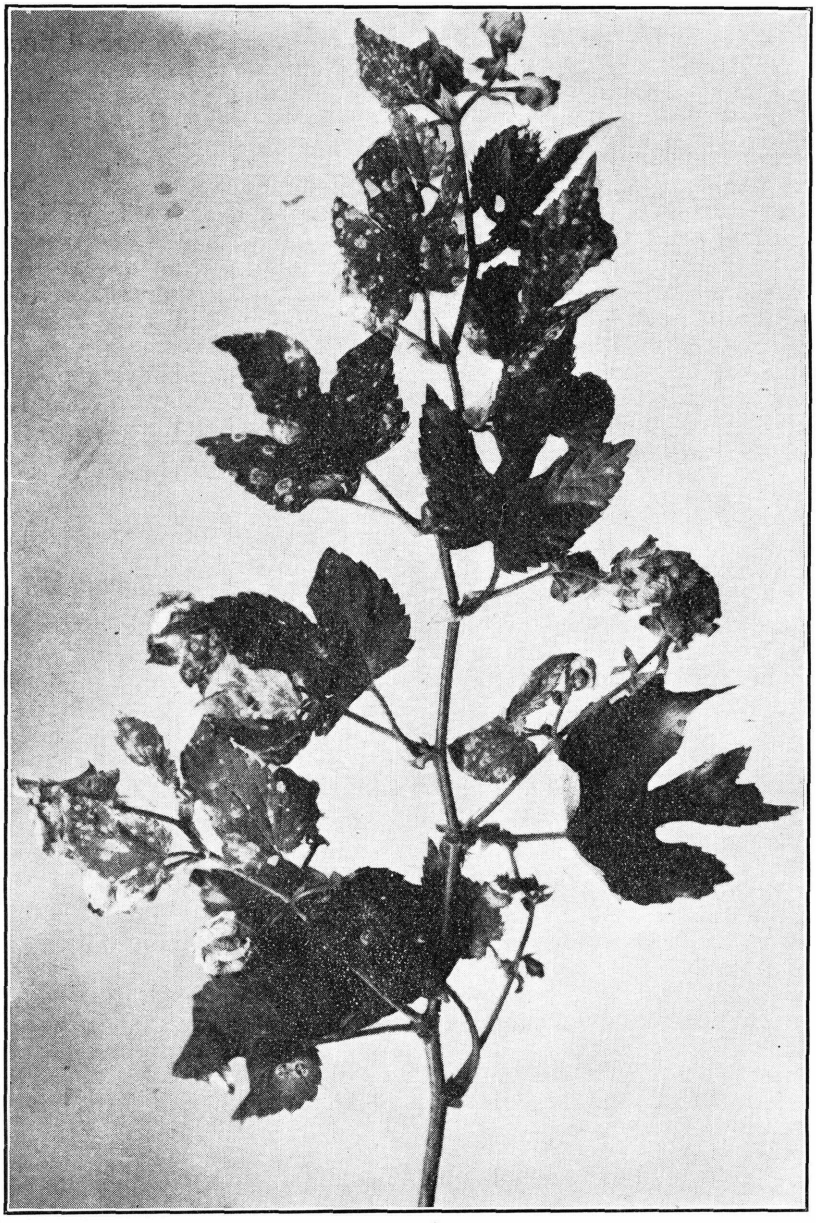

FIGURE 21.—Hop powdery mildew on leaves and young cones.

(*Hydroecia immanis* Grt.), comma butterfly (*Polygonia comma* Har.), hop butterfly (*Polygonia satyrus* Edw.), mourning cloak but-

terfly (*Aglais antiopa* Linn.), semicolon butterfly (*Polygonia interrogationis* Fabr.), hop flea beetle (*Psylliodes punctulata* Mels.), fall webworm (*Hyphantria cunea* Drury) and undetermined species of cutworms, leaf hoppers, loopers, mealy bugs, white flies, and wireworms.

The damage caused by most of these pests, however, seldom requires the extensive application of control measures. Growers are advised to consult their respective State experiment stations for information on the control of any of the pests not discussed in detail in this bulletin. The two most important pests that are responsible for serious annual losses in practically all hop-growing sections in the United States are the hop aphid and the common red spider.

THE HOP APHID

The hop aphid is pale yellowish green in the wingless form and green and black in the winged form. It spends the winter chiefly in the egg stage on plum and prune trees. The eggs hatch about the middle of April. The emerging aphids are wingless females, which, after about 2 weeks, deposit living young on prune foliage. Two or more generations are passed on prune trees before a generation of winged migratory forms are developed. The winged forms migrate to hops. Aphids are very weak fliers but, aided by wind, may travel one-half mile or more. The spring migration normally occurs about the middle of May and the spring migrants deposit living young on the hops. Approximately 10 days are required for the young to become mature.

Females deposit an average of 30 to 40 offspring and 11 or more generations may occur on hops during the summer months. Male aphids appear for the first time about the middle of September. Both males and females develop wings in the fall and return to prune trees where the eggs are deposited from the latter part of September to late in October.

Aphids injure hops in two ways: (1) They devitalize the plants by extracting the sap from the leaves, which results in decreased yields and generally lowered vitality of the infested plants; (2) they excrete honey dew in which sooty mold develops, greatly lowering or entirely destroying the market value of the moldy hops.

CONTROL OF THE HOP APHID

Parasites and predators often play an important role in the control of aphids, and in some seasons these useful insect allies are reported to have held the aphids in complete control. They are seldom present in sufficient numbers, however, to make additional control measures unnecessary.

Cultural methods, such as stripping the lower leaves and suckers from the vines, have supplementary control value, but additional and more direct control practices are usually necessary.

Hop aphids feed on the under sides of the leaves and, since they have sucking mouth parts, sprays or dusts must be used that kill by contact. Thorough coverage of infested plant parts and intimate contact of the insecticides with the insects is essential for effective control.

The most common insecticide used in combating hop aphids is nicotine sulfate applied as a liquid spray or as a dust. Two common formulas are as follows:

As a spray:	
Nicotine sulfate (40 percent)	1 pound.
Whale-oil soap	4–5 pounds.
Water	100 gallons.
As a dust:	
Nicotine sulfate (40 percent)	10 pounds.
Lime, hydrated	50 pounds.
Filler	40 pounds.

Another insecticide that has been used extensively by hop growers in the Pacific Northwest since 1889 for the control of aphids is quassia extract. It is not as rapid in action as nicotine sulfate, but seems to be effective over a longer period of time. The active ingredient, quassin, is obtained by soaking chips of quassia wood, a tropical tree, in water. The material seems to be more effective when used in combination with soap. There is no standard formula or method of preparation. A common formula follows:

Extract from 5 pounds of chips	3 gallons.
Whale-oil soap	5 pounds.
Water	100 gallons.

For best results the soap is first dissolved in a little hot water and poured into the cooking vat containing the required amount of water. The quassia chips are placed in a cloth bag and submerged in the soapy solution for 24 hours and followed by several hours of boiling.

Spraying should be avoided if possible during periods of excessive heat. High temperatures are favorable when dusts are employed, but the air should be quiet at the actual time of application. Any of the treatments used should begin before the infestation has become general and before the insects have infested the developing hop cones.

THE COMMON RED SPIDER

The common red spider is a serious pest in all important hop-growing sections of the United States. The adults are about one six-hundredths of an inch long and vary greatly in color. They may be greenish, yellowish, orange, or a mixture of green and yellow. They are profuse web spinners and infested plants are often covered with webs. The females overwinter as adults in the soil, in cracks and crevices of trees and poles, in trash and on grasses, weeds, and cultivated plants.

Activity of the adults is resumed in the spring and eggs are deposited during April and May on the under sides of leaves. Migration to hops occurs in early spring and may continue throughout the summer. Eighty or more eggs are deposited by the females over a period of about 10 days. The eggs hatch and grow into adults in from 20 to 27 days, depending upon temperatures. The number of generations per year also varies with temperature during the growing season. Nine generations are known to occur in the vicinity of Corvallis, Oreg.

The common red spider injures the hop plant by puncturing the lower leaf surfaces and withdrawing the sap. Each puncture usually

results in the appearance of a small light-colored spot on the leaf surfaces. The spots become more and more numerous as feeding continues and eventually the leaves become bronzed, shrivel, and die.

Late in the season the mites attack the cones and cause them to turn a reddish-brown color, rendering them unmarketable. The devitalization of the plants, which follows the serious infestation of these pests, is thought to affect their vitality the following season.

Low temperatures and excessive moisture are detrimental to the mites. Ordinarily they occur in very small numbers during early spring or until higher temperatures prevail and rains are less frequent. High temperatures and drought are ideal for their development and under such conditions may be expected to develop in abnormal numbers.

CONTROL OF THE COMMON RED SPIDER

Parasites and predators are reported to hold these pests in check during some seasons. Burning infested plants after harvest; suckering and stripping the vines; clean cultivation and ample irrigation are common practices among growers and may have some value. Most growers are forced to resort to spraying or dusting several times during a season in order to hold these pests in check.

Sulfur in some form is the standard control for the common red spider, although oil sprays and other materials are being tried.

A spray formula recommended in Oregon follows:

Commercial concentrated lime sulfur	2 gallons.
Casein spreader	½ pound.
Dusting sulfur	5 pounds.
Water to make	100 gallons.

Temperatures play an important part when lime sulfur is used as a liquid spray. Best results are obtained at high temperatures. Spraying in hopyards is a costly operation and many growers have largely abandoned the practice in favor of dusting. Dust mixtures consisting of various forms of sulfur with or without a maximum of 10 percent of hydrated lime or other filler are sometimes used. One formula has been used in commercial quantities which consists of 5 pounds nicotine sulfate (40 percent), 50 pounds of hydrated lime, and 45 pounds of dusting sulfur.

Power dusters are desirable, and weather conditions must be ideal to insure success. The use of sulfur dusts in sections where relatively high temperatures prevail has apparently given satisfactory control. Coverage, especially on the under sides of the hop leaves, should be thorough. Applications of dust should be begun before the mites have spun their webs if effective control is to be expected.

THE WESTERN SPOTTED CUCUMBER BEETLE

The western spotted cucumber beetle is fairly large with bright-green wing covers distinctly marked with 12 black spots. The adult beetles are often very numerous and feed on a wide variety of plants. Although hops are not generally considered one of their preferred food plants, they do occasionally cause considerable damage by feeding on hop leaves and the tender, rapidly growing shoots.

THRIPS

At least two species of thrips, particularly in dry seasons, may cause appreciable injury to hops on the Pacific coast. The onion thrips are light yellow and the western flower thrips are brownish yellow in color. Both insects are very small, not over five one-hundredths of an inch in length. They are often present in the flowers especially of male plants. They are thought to be responsible for the russeting of immature hop cones, a condition often mistaken for the effects of drought or the lack of proper fertilizing elements in the soil. The most conspicuous injury is caused to the lower leaves of plants that have not been heavily stripped. Injured leaves show discolored areas, tend to become dry and brittle, and curl upwards at the margins.

Both species are known carriers of certain virus diseases, and it is possible that they may be, in part, responsible for certain virose symptoms that are sometimes noted in infested hopyards on the Pacific coast.

THE OMNIVOROUS LEAF TIER

The omnivorous leaf tier is frequently responsible for considerable injury, particularly to hopyards in Oregon that are located near flax fields in which the insect is a common pest. The damage is caused by the larvae that feed on and destroy the terminal buds of the vines. The development of lateral shoots is stimulated at the points of injury. It often becomes necessary to train up these "side arms" to replace the damaged terminals. The cost of training is, as a result, materially increased.

THE HOP-PLANT BORER

The larvae of the hop-plant borer have caused serious losses to hop growers in New York State. Although the insect has been reported from Idaho and Oregon, it has never become of economic importance in the hop fields of the Pacific coast.

The moths become active in May and lay their eggs on the growing tips of the vines. The eggs hatch in a few days into minute, slender, green larvae spotted with black, that immediately burrow into the tips. Later in the season they drop to the ground and burrow into the bases of the vines, burrowing upward as well as underground. The stem is often entirely severed from the root or the vine badly stunted, so that it yields few if any hops. Adult moths are developed during August or September or the following spring.

HOP BUTTERFLIES

Four common species of butterflies occasionally cause injury to hops. The hop butterfly is widely distributed along the Pacific coast whereas the comma and semicolon butterflies are generally distributed east of the Rocky Mountains. The eggs, deposited in early spring on hopvines, hatch into larvae that feed on and sometimes completely destroy large numbers of vines.

The mourning cloak butterfly is widely distributed throughout the United States. Although not common, they have been reported as attacking and causing some damage to hops in Oregon.

THE HOP FLEA BEETLE

The hop flea beetles, small black beetles, are serious pests in British Columbia but as yet do little damage in any of the hop-growing sections in the western United States. There is but one generation a year. The beetles pass the winter as adults. They may be found feeding on nettles in early March whenever temperatures reach 40° to 50° F. Feeding on hop foliage becomes general until the peak of adult population is reached in May. Eggs are deposited from 2 to 3 inches beneath the soil surfaces during the period of spring activity. The developing larvae feed on the roots of hops and other plants. The summer brood of adults appears in late July when the beetles again feed on hop foliage.

THE FALL WEBWORM

The larvae of the fall webworm feed on many different kinds of plants. Occasionally their feeding does serious damage to hops. Natural enemies usually hold the pests in check.

STANDARDS OF QUALITY

In the successful growing of hops, quality is an important factor, but, unfortunately, growers usually give more attention to yields than quality. High yields are of course desirable, but unless they combine quality they may not react to the benefit of the grower. The purchaser sometimes judges hops according to their geographical origin which, however, is not always a true indication of quality. Heretofore hops have been judged almost entirely by physical appearance; that is, on the basis of color, condition (broken cones, molds, and insect damage), odor, stickiness (lupulin), and cleanliness (leaves and stems). These properties only roughly establish the quality of hops and do not accurately indicate the amount of bitter principles present that determine their true value. Moreover, opinions regarding the quality of hops when judged by physical means will naturally differ according to the individual; therefore this method is entirely inadequate to determine relative quality.

With the introduction of chemical methods for the determination of the desirable constituents of hops, it is now possible to obtain a more accurate measure of their value to the brewer. Also, the quantity of seeds, leaves, and stems in hops can now be determined with accuracy. If and when standard methods that are now under consideration, both physical and chemical, for the rational evaluation of hops are put into effect and used by brewers generally, growers must necessarily give careful attention to the production of hops of highest quality.

ACREAGE AND YIELD

Since 1914 the largest area of hops harvested was 44,653 acres in 1916, and the smallest 18,440 in 1924. The acreage harvested, yields per acre, and production of hops in the United States from 1915 to 1938, and in California, Oregon, and Washington from 1930 to 1938, inclusive, are presented in tables 1 and 2, respectively. Similar data for New York from 1918 to 1937 are given in table 3. The acreage

harvested each season is frequently influenced by damage from diseases and by labor conditions at the time of picking.

TABLE 1.—*Acreage, average yield per acre, and production of hops in the United States, 1915–38* [1]

Year beginning July	Acreage harvested	Average yield per acre	Production	Year beginning July	Acreage harvested	Average yield per acre	Production
	Acres	*Pounds*	*1,000 pounds*		*Acres*	*Pounds*	*1,000 pounds*
1915–16	44,653	1,187	52,986	1927–28	24,600	1,246	30,658
1916–17	43,900	1,152	50,595	1928–29	26,200	1,257	32,944
1917–18	29,900	983	29,388	1929–30	24,400	1,360	33,195
1918–19	25,900	829	21,481	1930–31	19,500	1,202	23,447
1919–20	22,000	1,287	28,320	1931–32	21,400	1,234	26,410
1920–21	27,000	1,243	33,555	1932–33	22,000	1,094	24,058
1921–22	27,000	1,087	29,340	1933–34	30,300	1,319	39,965
1922–23	23,400	1,186	27,744	1934–35	36,800	1,194	[2] 43,952
1923–24	18,440	1,071	19,751	1935–36	38,900	1,227	[2] 47,746
1924–25	20,350	1,360	27,670	1936–37	30,900	814	25,156
1925–26	20,350	1,404	28,573	1937–38	34,100	1,302	[2] 44,399
1926–27	20,800	1,516	31,522	1938–39 [3]	32,600	1,160	37,805

[1] Compiled from statistics furnished by the Bureau of Agricultural Economics, U. S. Department of Agriculture.
[2] Includes 802,000 pounds in 1934–35, 5,436,000 pounds in 1935–36, and 4,365,000 pounds in 1937–38 not harvested on account of labor shortage and market conditions.
[3] Preliminary.

TABLE 2.—*Acreage harvested, yield per acre, and production of hops, by States, average 1930–34 and 1935–38* [1]

State	Acreage harvested					Yield per acre				
	Average, 1930–34	1935	1936	1937	1938 [2]	Average, 1930–34	1935	1936	1937	1938 [2]
	Acres	*Acres*	*Acres*	*Acres*	*Acres*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
California	3,620	6,900	5,400	6,800	6,600	1,590	1,600	1,250	1,630	1,650
Oregon	17,400	26,000	21,000	22,300	21,500	999	992	530	1,100	850
Washington	4,980	6,000	4,500	5,000	4,500	1,740	1,819	1,617	1,757	1,920
United States	26,000	38,900	30,900	34,100	32,600	1,209	1,227	814	1,302	1,160

State	Production				
	Average, 1930–34	1935	1936	1937	1938 [2]
	1,000 pounds	*1,000 pounds*	*1,000 pounds*	*1,000 pounds*	*1,000 pounds*
California	7,881	[3] 11,040	6,750	[4] 11,084	10,890
Oregon	17,325	[3] 25,792	11,130	[4] 24,530	18,275
Washington	6,361	[3] 10,914	7,276	[4] 8,785	8,640
United States	31,567	[3] 47,746	25,156	[4] 44,399	37,805

[1] Compiled by the Bureau of Agricultural Economics, U. S. Department of Agriculture.
[2] Preliminary.
[3] Includes the following quantities not harvested on account of labor shortage and market conditions: California, 586,000 pounds; Oregon, 2,250,000 pounds; Washington, 2,600,000 pounds.
[4] Includes the following quantities not harvested on account of labor shortage and market conditions: California, 475,000 pounds; Oregon, 2,530,000 pounds; Washington, 1,360,000 pounds.

TABLE 3.—*Acreage, average yield per acre, and production of hops in New York, 1918–37*

Year	Acreage harvested	Average yield per acre	Production	Year	Acreage harvested	Average yield per acre	Production
	Acres	*Pounds*	*Pounds*		*Acres*	*Pounds*	*Pounds*
1918 [1]	3,800	330	1,254,000	1929	17	466	7,920
1919	2,300	690	1,587,000	1930–32	(3)	(3)	(3)
1920	1,000	950	950,000	1933	29	483	14,000
1921	1,000	580	580,000	1934	85	671	57,000
1922–24 [2]	(3)	(3)	(3)	1935	120	667	80,000
1925	(3)	(3)	962,200	1936	200	425	85,000
1926	(3)	(3)	106,190	1937	220	636	140,000
1927–28	(3)	(3)	(3)				

[1] Figures for 1918 to 1921 from Yearbooks of the Department of Agriculture.
[2] Figures from 1922 to 1937, inclusive, furnished by the New York State Agricultural Experiment Station, Geneva, N. Y.
[3] Not reported.

The yield of hops varies widely according to locality, and within the locality according to season, soil conditions, methods of cultivation, varieties grown, and the prevalence of insect pests and diseases.

In seasons of good production, on the better soils, the yields of individual yards will usually be much larger than the averages shown in the tables. In California an acre may produce 1,400 to 2,200 pounds; in Washington, 1,200 to 2,000 pounds; in Oregon, 1,000 to 1,600 pounds; and in New York, 800 to 1,500 pounds.

COST OF PRODUCTION

Many of the items that must be taken into consideration when determining the cost of producing hops will differ with the season and the locality. They cannot always be easily predicted or accurately estimated.

Expenditures for cultural labor and material are often reduced to a minimum in years of unfavorable market conditions and materially affect the cost of production, as do unusually low yields due to unexpected losses caused by diseases or insect pests.

No official reports of cost-of-production studies are available for the States of New York or Washington. Two independent studies of the cost of producing hops on the Pacific coast, however, have been made covering the years 1934 to 1936 for Sonoma County by the Extension Service of the University of California, and for the entire State of Oregon by the Oregon Agricultural Experiment Station. Both studies showed that although harvesting costs are increased by an increase in yield, preharvest costs, under normal conditions, remain practically the same. As a result the total cost of production per pound is progressively decreased as the yield is increased.

The average total first-year cost of establishing hopyards in Oregon was $81.67 and the average total bearing hopyard investment was $355 per acre. During the 3-year period the average total cost of producing hops was 18.6 cents per pound.

In Sonoma County, Calif., the average total cost over the 3-year period was 21.1 cents per pound.

MARKETING

The most serious problem that has always confronted the hop grower is the sale of his crops at prices that will give a fair return

on his investment and labor. Owing in part to great fluctuations in prices, hop growing from a business point of view is an extremely uncertain enterprise. The state of the market is determined largely by the stock of hops held in storage from the previous year or years, by the crop conditions or prospects at home and abroad during the current year, and by the probable demand as judged from a comparison of the two conditions just mentioned. Although the state of the market is conditioned by these three factors, it is also materially influenced by the dealers, hop merchants, or middlemen, who stand between grower and consumer.

Hops may move into the market in a number of ways and reach the consumer through various channels. Only a small percentage of hop growers sell direct to consumers, so the bulk of the hops passes through the hands of middlemen. Sales may be made to the large dealer direct through his buyers or to the local dealer, who in turn sells to the large dealer. Growers may also sell through a commission merchant, who may act as agent for both grower and consumer. The broker, or factor, serves as a go-between for dealers or for dealer and consumer. All these middlemen occupy a recognized legitimate place in the trade so long as they confine their operations to buying and selling at market prices as fixed by supply and demand and depend for their profits upon the favorable terms that they may be able to make in the regular course of trading. Under existing conditions the hop crop probably could not be marketed without the middlemen. Growers with small holdings remote from consumers could scarcely find a market for their products, even if the difficulties involved in arranging credit were overcome. The grower is usually in need of money and demands immediate payment; on the other hand, the consumer may not have funds available to pay cash for his hops at the time when it is necessary to make the purchase. The dealer solves the difficulty by relieving the grower of his stock and making cash payment therefor or a suitable short-time arrangement and by selling to the consumer on terms to suit his convenience. The grower is often unable, through customary channels, to secure the necessary funds with which to produce a crop and prepare it for market. Advances by dealers against contracts, for all or a portion of a prospective crop, are often his only recourse. This practice does not always react to the advantage of producers. Such advances are often below actual cost of production, they tend to establish the market prices at a fictitious minimum, and they encourage overproduction and consequent market depression by assisting in the maintenance of acreage that otherwise might remain out of production.

The present generally unsatisfactory marketing situation might be improved in several ways, particularly by careful reference by growers to available official statistics of production and consumption. By this means they could not only govern their acreage according to the prospective demand, but by knowing the amount of hops consumed during the current year, the stocks remaining in the hands of the consumers, and the crop conditions at home and abroad, they could form an intelligent opinion as to the probable relation between supply and demand and what prices might be reasonably expected.

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